SEA OTTERS, SHELLFISH, AND HUMANS: 10,000 YEARS OF ECOLOGICAL INTERACTION ON SAN MIGUEL ISLAND, CALIFORNIA

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Abstract—We use data from San Miguel Island shell middens spanning much of the past 10,000 years in a preliminary exploration of long-term ecological relationships between humans, sea otters (*Enhydra lutris*), shellfish, and kelp forests. At Daisy Cave, human use of marine habitats begins almost 11,500 years ago, with the earliest evidence for shellfish harvesting (11,500 cal BP), intensive kelp bed fishing (ca. 10,000–8,500 cal BP), and sea otter hunting (ca. 8,900 cal BP) from the Pacific Coast of North America. On San Miguel Island, Native Americans appear to have coexisted with sea otters and productive shellfish populations for over 9,000 years, but the emphasis of shellfish harvesting changed over time. Knowledge of modern sea otter behavior and ecology suggests that shell middens dominated by large red abalone shells (*Haliotis rufescens*)—relatively common on San Miguel between about 7,300 and 3,300 years ago—are only likely to have formed in areas where sea otter populations had been reduced by Native hunting or other causes. Preliminary analysis of lenses, in which the remains of urchins are unusually abundant, may also signal an increasing impact of Island Chumash populations on kelp forest and other near shore habitats during the late Holocene. Such impacts were probably relatively limited, however, when compared to the rapid and severe disruption caused by commercial exploitation under the Spanish, Mexican, and American regimes of historic times.

Keywords: archaeology, ecology, history, kelp forests, sea otters, Enhydra lutris, shellfish

INTRODUCTION

In recent decades, the expansion of sea otter (*Enhydra lutris*) populations along the central California Coast has devastated once productive abalone and sea urchin fisheries that developed in this predator's absence, creating tensions between resource managers, fishermen, and environmentalists over the protection and management of sea otter populations. Archaeological data from San Miguel Island suggest, however, that Native Americans, sea otters, and productive shellfish populations coexisted on the northern Channel Islands for thousands of years (Walker 1982). These apparently contradictory data sets raise fundamental questions about the nature of "pristine" prehistoric sea otter and shellfish populations, how Native American harvests were sustained over the millennia, the possible ecological effects of sea otter hunting prior to European contact, and the management of modern sea otter populations and healthy marine ecosystems along the California Coast.

In this paper we examine some of these issues through the lens of historical ecology, using modern ecological observations, historical accounts, and a 10,000 year archaeological sequence from San Miguel Island to explore the relationships between humans, sea otters, shellfish, and Channel Island kelp forests through time. Although some of our interpretations are speculative, our samples are relatively small, and our archaeological data preliminary, they provide food for thought and fuel for further research. To contextualize the data and discussion presented below, we first provide some cultural and ecological background information.

SAN MIGUEL ISLAND: GEOGRAPHY, ECOLOGY, AND HISTORY

Located about 44 km off the Santa Barbara Coast, San Miguel is the westernmost and second smallest of the northern Channel Islands. As recently as 12,000 years ago, when sea levels were about 50 m lower than present, San Miguel was part of the larger island of Santarosae, which included the modern expressions of Anacapa, Santa Cruz, Santa Rosa, and San Miguel islands (Orr 1968). Today, San Miguel is an arid island roughly 15 km long and 8 km wide, with a total land area of about 37 km^2. Maximum elevation is 256 m, freshwater sources are relatively limited, and much of the island consists of tilted tablelands cut by wave action during periods of higher relative sea level. Dunes are extensive and the coast consists of roughly equal amounts of sandy and rocky shoreline (Johnson 1972). The littoral sand supply increased dramatically after historical overgrazing, however, and rocky shorelines may have been more dominant during much of the past 15,000 years than they are today. This proposition is supported by the presence of numerous archaeological sites (shell middens) containing millions of shells from rocky coast mollusks in areas now characterized by sandy shorelines.

The diversity and productivity of terrestrial plants and animals on San Miguel Island is limited (Rick et al. 2001). Pine forests were present until near the end of the Pleistocene, but Holocene plant communities were dominated by low scrub and grassland communities that offered little to human foragers. Although pygmy mammoths (*Mammuthus exilis*) survived until near the end of the Pleistocene, Holocene land mammals were restricted largely to dogs, foxes, skunks, and mice. Compared to this relatively depauparate landscape, the marine environment around San Miguel is rich in resources. Intensive upwelling supports a diverse and productive marine ecosystem, with extensive and biologically complex kelp forest and rocky coast habitats. Offshore waters are home to a variety of cetaceans (whales, dolphins, and porpoises), other marine mammals (seals, sea lions, sea otters), numerous teleost and elasmobranch fishes, shellfish (abalones, mussels, sea urchins, etc.), and seabirds.

Archaeological evidence suggests that maritime peoples first colonized the northern Channel Islands at least 12,000–13,000 years ago (Johnson et al. 2002). On San Miguel, the earliest indication of human occupation comes from a sparse shell midden stratum at Daisy Cave dated to about 11,500 cal BP (Erlandson et al. 1996). From about 10,000 years ago to historic times, we have nearly continuous occupation records from the island's north coast and we are currently building a 9000 year sequence from the south coast (Braje et al. 2004). San Miguel contains over 600 recorded archaeological sites, including many large shell middens occupied on numerous occasions. For instance, sites SMI-481 and SMI-470, located at or near Otter Point, extend for over 500 m along the coast and contain at least 13 separate occupations dated between about 7,300 years ago and AD 1820. These shell middens, built in calcareous dunes, contain the well-preserved remains of shellfish, fish, marine mammals, and birds, as well as artifacts made from stone, shell, and bone. Although systematic sampling of San Miguel Island shell middens has been limited, the faunal remains provide an outstanding record of human interaction with past island ecosystems. At Daisy Cave, for instance, the remains of at least 140 discrete animal taxa have been identified, including several extinct species (Erlandson 2004). Artifacts also record the changing technologies that maritime peoples used to harvest the sea and variation in the number and size of dated sites allows rough estimates of the number of people who lived on the island at different times.

Two historic Chumash villages are known for San Miguel, with an estimated population in AD 1796 of about 50 people. Archaeological data suggest that Chumash populations on San Miguel were probably considerably larger than this, with several substantial village sites dated to the period just prior to European colonization (Rick 2004). The first contacts between Europeans and the Island Chumash came in AD 1542, 240 years before the establishment of Mission Santa Barbara, when Spanish ships commanded by Juan Rodriguez Cabrillo wintered on San Miguel Island (Wagner 1929). The Island Chumash may have been devastated by Old World diseases transmitted during such Protohistoric contacts (see Erlandson et al. 2001), but historic accounts suggest that they were thriving when the Spanish first colonized Alta California in AD 1769. Beginning about 1,000 years earlier, Chumash population densities were among the highest recorded for hunter-gatherers anywhere in the world and the Island Chumash were integrated into a regional economy fueled by extensive trade networks, widespread craft specialization, and the use of shell bead currency (Kennett 1998, Arnold 2001). Ethnohistoric accounts indicate that sea otters were highly valued by the Chumash for their furs, which were used to make capes, robes, and blankets (Hudson and Blackburn 1985, pp. 43–45, 52–54; King 1990, p. 52). Along with shell beads, sea otter furs may have been one of the major commodities islanders exported to the mainland Chumash and neighboring tribes.

SEA OTTERS AND SHELLFISH IN HISTORICAL PERSPECTIVE

We know little about the demography of Channel Island sea otter populations after Spanish colonization, except that sea otters were hunted to the brink of extinction within a few decades. With the development of a global market for sea otter furs in the 18th century, intensive otter hunting came under the control of Russian, Spanish, English, and American mercantile powers. During the Mission period (AD 1769–1822), Spanish authorities attempted to control the maritime trade in sea otter furs along the Alta and Baja California coasts. The effectiveness of Spanish trade in otter furs appears to have been limited, however, as was their success in stopping American and Russian poachers and smugglers (see Ogden 1941). Early in the Mission period, otter hunting on the Channel Islands may have been conducted primarily by Chumash hunters, who traded pelts to Spanish, American, or Russian merchants. Between AD 1803 and 1822, American and Russian ship captains used Native Alaskan hunters to illegally hunt otters off the California Coast, sometimes leaving groups of hunters on the Channel Islands for weeks or months. A Russian supervisor for one ill-fated party of 24 Aleuts caught by Spanish authorities confessed to taking 955 otter skins in a seven month stay on San Nicolas Island (Ogden 1941, p. 62), an amazing yield for such a small island. For a time after AD 1822, the Mexican government initiated a more liberal trade policy, allowing foreign merchants to trade legally for otter furs and even entering cooperative hunting agreements with Russian and other foreign concerns (Ogden 1941). According to Scammon (1968, p. 170), the Mexican government later outlawed sea otter hunting along the Alta and Baja California coasts, but enforcement on the relatively remote Channel Islands was probably difficult and relatively ineffective. By the 1850s, sea otters had been nearly eradicated from California, with small herds persisting only in isolated pockets of the central coast. Prior to their extirpation, Scammon (1968, p. 169) noted that San Miguel Island was one of the better places to hunt sea otters along the Pacific Coast.

Archaeological data are of variable quality and sample sizes are generally small, but preliminary evidence suggests that sea otters were hunted by the Chumash and their ancestors on San Miguel from at least 9,000 years ago until about AD 1800 (Table 1). The earliest records of sea otter hunting come from Strata E and C at Daisy Cave, dated to ca. 9,000–8,600 and 6,700 years respectively. Evidence for sea otter hunting during the middle Holocene is relatively sparse, probably because few middle Holocene sites have been investigated. One of the largest assemblages of identified otter bones ($n = 24$; Table 2) from the island comes from SMI-1, however, a large site thought to date primarily to the middle Holocene (Erlandson 1991). At SMI-1, which was also occupied during the early and late Holocene, sea otters make up about 16% of the identified sea mammal remains (Walker 1978), which are dominated by California sea lion (*Zalophus californianus*, 37%), harbor seal (*Phoca vitulina*, 25%), and Guadalupe fur seal (*Arctocephalus townsendi*, 22%). At other sites spanning much of the last 3,000 years, dated records of otter hunting are nearly continuous until the early 1800s when the last Chumash were removed from the island. For instance, at SMI-525 near Point Bennett, Rozaire excavated a stratified shell midden roughly 3.5 m deep, deposits now known to date between about 3,200 and 500 years ago. Although Rozaire excavated SMI-525 in arbitrary 6-inch levels that do not conform to the natural stratigraphy, Walker (1978) documented that sea otters and other pinnipeds were present throughout the sequence (Table 3) and that sub-adult individuals comprise roughly 35% of the

Table 1. Sea otter (*Enhydra lutris*) remains from dated archaeological sites on San Miguel Island (SMI), CA.

Site and provenience	Age range (cal BP)[a]	Wt. (g)	NISP: Elements or notes[b]
SMI-261 (Daisy Cave), Str. E2	8,900–8,800 yrs	2.41	1: left mandibular 2nd molar (see also Table 2)
SMI-261, Str. E1b	8,750–8,650 yrs	2.62	1: vertebra, juvenile (see also Table 2)
SMI-261, Str. C	6,800–6,600 yrs	17.6	1: maxilla fragment with 6 teeth
SMI-1	7,000–3,350 yrs?	n/a	24: 15.9% of sea mammals (see Table 2)
SMI-481	6,000–5,900 yrs	10.9	1: rib from small bulk sample
SMI-87	3,100–2,400 yrs	n/a	15: MNI=4; mostly axial elements
SMI-525	3,100–500 yrs	n/a	MNI=26 (see Table 3)
SMI-488: surface	2,800–2,600 yrs?	n/a	17: cranial and postcranial
SMI-481	1,700–1,500 yrs	n/a	2: mandibles (1 MNI) from surface
SMI-528, Str. I	1,450–1,200 yrs	n/a	32: 18.5% of sea mammals
SMI-492N: Str. 9, 11	1,400–1,200 yrs	n/a	2: vertebra, humerus; from column samples
SMI-481	1,250–1,050 yrs	n/a	24: MNI=5; cranial and post-cranial
SMI-602	600–400 yrs	n/a	23: 17.6% of sea mammals
SMI-163	300–150 yrs	13.96	1: 12.5% of sea mammal MNI

[a] All dates are calibrated ^{14}C ages expressed in calendar years before present (AD 1950).
[b] NISP = number of individual specimens; MNI = minimum number of individuals. These samples come from a variety of surface and subsurface contexts and assemblages of widely varying size (data compiled from Walker 1978, Walker and Snethkamp 1984, Erlandson 1991, Walker et al. 2002, Rick 2004, Vellanoweth et al. 2004 unpubl. data).

otters represented in the assemblage. Despite some gaps in the archaeological record, only a small percentage of San Miguel Island sites have been excavated and dated. It seems likely, therefore, that sea otters were present in island waters throughout the Holocene—until they were eradicated by intensive commercial hunting in the mid-1800s.

HUMANS, SEA OTTERS, AND KELP FOREST ECOLOGY

Kelp forests, which grow along many temperate and cool-water coastlines around the world, are some of the most productive ecological communities on earth. In historic times, research has shown that many of the world's kelp beds are highly susceptible to ecological disruption due to human impacts associated with overfishing, pollution, and other activities (Jackson et al. 2001, Steneck et al. 2002). Along the California Coast, giant kelp (*Macrocystis pyrifera)* and bull kelp (*Nereocystis luetkeana)* forests grow rapidly, contributing large amounts of organic material to coastal ecosystems. Such kelp forests enhance secondary marine productivity, providing nutrients and shelter to a wide range of shellfish, fish, and other marine species (Duggins et al. 1989), and they also subsidize terrestrial productivity (Polis et al. 1997). Along the Santa Barbara Coast and the northern Channel Islands, the productive fisheries supported by extensive kelp forests were a major contributor to the high population densities attained by the Chumash prior to European contact (Glassow and Wilcoxon 1988).

Sea otters and their immediate ancestors have played a key role in structuring kelp forest ecosystems along the Pacific Coast of North America for several million years (Simenstad et al. 1978, Dayton and Tegner 1984, Dayton 1985, Estes and Steinberg 1988). When present, sea otters strongly influence kelp forest food webs, serving as important predators that feed primarily on shellfish in near shore waters. Ecological studies have shown that otters feed preferentially on larger abalones (*Haliotis* spp.), sea urchins (*Strongylocentrotus* spp.), and crabs (*Cancer* spp.), shifting to mussels (*Mytilus californianus*) and other fish and shellfish species as their preferred prey is reduced (Estes et al. 1981). In North Pacific kelp forests, sea otter predation controls the density and distribution of sea urchins, which feed primarily on kelp. In Alaska and British Columbia,

Table 2. Number of identified sea otter and pinniped bones from excavations at SMI-1 and SMI-261, San Miguel Island, CA[a].

Site (SMI-) level (inches)	Sea otter	Guadalupe fur seal[b]	Northern fur seal	Undiff. fur seal	California sea lion	Harbor seal	Total
1: 6–12	7	4	0	0	12	13	36
1: 12–18	16	22	0	0	38	16	92
1: 18–24	1	7	0	0	6	4	18
1: 24–30	0	0	0	0	0	5	5
Subtotal	24	33	0	0	56	38	151
261: 0–6	1	1	0	5	2	0	9
261: 6–12	8	1	0	1	1	2	13
261: 12–18	1	1	0	2	3	0	7
261: 18–24	5	0	2	2	0	1	10
261: 24–30	1	0	0	0	0	0	1
261: 30–36	0	0	0	2	2	0	4
261: 36–42	1	0	0	0	1	0	2
261: 42–48	0	0	0	1	0	0	1
261: 48–54	2	1	0	1	0	0	4
Other	0	0	1	1	0	0	2
Subtotal	19	4	3	15	9	3	53
Grand Totals	43	37	3	15	65	41	204

[a] Data compiled from Walker (1978); numbers are for identifiable skeletal elements only, undifferentiated otariid or sea mammal remains are not included. Excavation levels cannot be confidently attributed to specific time periods, but SMI-1 was occupied several times between about 7,000 and 1,000 years ago and SMI-261 was occupied multiple times between about 11,700 and 700 years ago.
[b] Northern fur seal (*Callorhinus ursinus*).

the removal or depletion of sea otters has dramatically effected shellfish populations and kelp forest habitats (Estes and Duggins 1995, Steneck et al. 2002). When sea otters are present, they keep sea urchins in check and limit them primarily to crevices and cracks where they feed on drift kelp. When sea otters are removed or severely depleted, however, urchin populations are released from predation pressure. Expanding rapidly, urchin populations move onto the open ocean floor, feed directly on growing kelp, and can transform three dimensional kelp forest habitats into relatively depauparate and essentially two-dimensional urchin barrens.

In historical times, much of the Aleutian Island chain has seen at least two cycles of widespread collapse of kelp forests due to the intensive hunting of sea otters and a subsequent explosion of urchin populations. Russian-controlled sea otter hunting in historic times led to extensive deforestation of lush kelp beds that once surrounded much of the island chain (Estes and Palmisano 1974). More recently, heavy predation on sea otters by killer whales (*Orcinus orca*) caused another episode of deforestation (Estes et al. 1998). Using archaeological records on the size and abundance of urchin remains found in some Aleutian shell middens, Simenstad et al. (1978) also suggested that heavy Aleut sea otter hunting may have caused such trophic cascades prior to European contact. Dayton (1985, p. 234) and Dayton and Tegner (1984, p. 471) argued that Native American hunters may also have controlled sea otter populations along the California Coast, releasing shellfish from predation pressure.

Southern California kelp forests are more complex than their Aleutian counterparts, with more diverse food webs and a wider array of urchin predators, including the California sheephead (*Semicossyphus pulcher*) and spiny lobster (*Panulirus interruptus*) (Foster and Schiel 1985, Jackson et al. 2001, Graham 2004). Because of the complexity of California kelp ecosystems, even the near extinction of sea otters in the mid-1800s did not cause a wholesale collapse of kelp forests comparable to those documented in the Aleutians (Dayton and Tegner 1984, p. 471; Foster and Schiel 1988, Steneck et al. 2002). Although California kelp

Table 3. Sea otter and pinniped remains (MNI) from LACMNH excavations at SMI-525, San Miguel Island, CA[a].

Level (inches)	Sea otter	Guadalupe fur seal	Northern fur seal	Elephant seal[b]	California sea lion	Steller sea lion[b]	Harbor seal	Total
18–24	1	3	0	1	2	0	0	7
24–30	1	4	0	0	1	0	0	6
30–36	2	3	0	1	2	1	1	10
36–42	2	4	0	1	4	1	1	13
42–48	2	5	2	1	1	0	1	12
48–54	4	5	0	0	1	0	2	12
54–60	1	2	1	4	2	0	0	10
60–66	0	0	0	0	2	0	0	2
66–72	0	0	0	0	0	0	0	0
72–78	2	3	0	0	3	0	1	9
78–84	1	3	0	0	0	0	0	4
84–90	2	3	0	0	2	0	0	7
90–96	1	4	0	0	2	1	1	9
96–102	1	2	1	1	1	1	1	8
102–108	1	1	0	0	0	0	0	2
108–114	1	1	0	1	1	0	0	4
114–120	1	1	0	0	1	0	1	4
120–126	1	0	0	1	2	0	0	4
126–132	1	2	0	0	0	0	0	3
132–138	1	0	0	0	0	0	0	1
Totals	26	46	4	11	27	4	9	127

[a] Data compiled from Walker (1978); MNI = minimum number of individual animals represented; data are for identifiable skeletal elements only, undifferentiated otariid or sea mammal remains were not quantified. Excavation levels cannot be confidently attributed to discrete time periods, but SMI-525 was occupied repeatedly between about 500 and 3,200 years ago.
[b] Elephant seal (*Mirounga angustirostris*); Steller sea lion (*Eumetopias jubatus*).

forests are vulnerable to a wider range of historic disturbances (El Niño, substrate changes, pollution, etc.), causing cyclical fluctuations in their distribution and productivity, their overall diversity may make them more resistant to catastrophic collapse due to human impacts (Steneck et al. 2002). After the historical extirpation of sea otters and the collapse of Native American populations (and their traditional foraging economies), many California kelp forest communities supported anomalously large populations of abalones, sea urchins, and perhaps lobsters—and thus highly productive commercial fisheries. For some time, urchin populations may have been held in check by the predation of sheephead and lobster, as well as competition with abalones, but intensive commercial and sport fishing for these species eventually caused deforestation of some southern California kelp beds and the formation of extensive urchin barrens (Salls 1991).

Ecological monitoring of central California sea otters as they expanded into "new" areas of their historical range has also demonstrated their devastating impact on shellfish fisheries (Estes and VanBlaricom 1985, and references therein). It is also generally agreed that the presence of sea otters inhibits the formation of urchin barrens and limits the potential for urchin-caused deforestation and related reductions in the diversity and abundance of fish and other species available for human exploitation (Estes and Duggins 1995, VanBlaricom and Estes 1988).

VanBlaricom (1988, p. 88) recognized that Native Americans affected the nature and structure of sea otter and shellfish populations along the Pacific Coast of North America for millennia and suggested that developing complete models of coastal ecosystems required an understanding of such early human impacts. Most ecological studies of sea otter and shellfish populations, kelp forests, and other marine communities along the California Coast (and beyond) have been conducted in a historical vacuum that does not recognize the long history of human interaction with coastal ecosystems or the influence that large and technologically sophisticated Native populations had on supposedly "pristine" ecosystems over the millennia (Jackson et al. 2001). This temporal provincialism provides baselines for the historical size of animal populations and the structure of past ecological communities that are fundamentally flawed.

HUMAN ALTERATION OF NEAR SHORE COMMUNITIES: THE ARCHAEOLOGICAL RECORD

California's Channel Islands contain an archaeological record of human interaction with marine ecosystems that is ideally suited to historical ecology. Because the Chumash and their ancestors hunted otters, fished for sheephead, and gathered sea urchins on the Channel Islands for millennia (Rick et al. 2001, Erlandson et al. 2004), they may have altered the structure of kelp forest and other near shore communities in ways that are visible in island archaeological sites. With the possible exception of pinniped populations (see Hildebrandt and Jones 1992, Jones and Hildebrandt 1995, Porcasi et al. 2000, Walker et al. 2002), such impacts are less likely to have been significant early in the history of island settlement, when relatively few people were present on the islands. As human populations expanded in the middle and late Holocene, however, the potential for significant impacts on island habitats also grew. The increasing sophistication of Chumash maritime technology, including the development of circular shell fishhooks about 2,500 years ago (Rick et al. 2002), and an intensification of trade with mainland peoples after about 1,500 years ago (Kennett 1998), also suggest that human impacts on the marine ecosystem may have increased through time.

Red Abalone Middens and Sea Otters

Possible evidence for the human alteration of California kelp forest ecosystems prior to European contact is found in shellfish assemblages from Channel Island middens. On San Miguel, as many as 16 shell middens have been dated between about 10,000 and 8,000 years ago. These early sites generally contain shellfish assemblages dominated by California mussels (*Mytilus californianus*), with lesser amounts of black abalones (*H. cracherodii*), turban snails (*Tegula funebralis*), owl limpets (*Lottia gigantea*), and other rocky intertidal species (Table 4). Red abalone shells (*H. rufescens*) are present in some of these early middens, but only in small amounts. However, between about 7,300 and 3,000 years ago large red abalone shells are abundant in many San Miguel middens. These red abalone middens, which vary in size and setting, have been found around the entire perimeter of the island. Along with hundreds of large red abalone shells that visually dominate the midden deposits, the sites often contain a variety of other shellfish. Similar red abalone middens are found on Santa Rosa, Santa Cruz, and San Nicolas islands (Glassow 1993), where they date to the same general time period, as well as some mainland sites along the central California Coast, where their temporal distribution is less well known. On the Channel Islands, red abalone middens have been interpreted as evidence for the movement of red abalones into the intertidal zone during periods of colder sea surface temperatures (Glassow et al. 1994), the exploitation of localized upwelling zones by human foragers (Sharp 2000), for subtidal diving by Native people (Vellanoweth 1995), and as specialized shellfish drying sites (Kennett 1998).

Whatever the underlying reason for the proliferation of red abalone middens on the Channel Islands during the middle Holocene, modern ecological studies suggest that an abundance of large abalones accessible to human foragers is fundamentally incompatible with the presence of significant numbers of sea otters in local waters (see Estes and VanBlaricom 1985, Laur et al. 1988). The abundance of large abalones—the preferred food of California sea otters—in many San Miguel Island shell middens spanning over 4,000 years suggests that otter populations were limited by predation rather than a shortage of food. The presence of sea otter bones in San Miguel middens spanning the past 9,000 years indicates that human hunting may have limited otter populations, but that sea otters probably were never completely eradicated from San Miguel Island waters.

If Native hunters eliminated otters from certain areas, they may well have noticed an increased

Table 4. Sea urchin and other major shellfish as contributors (%) to dated San Miguel Island (SMI) shell middens.

Site (SMI-): Stratum or Depth	Age (cal BP)[a]	Sea urchin[b]	California mussel	Black abalone	Red abalone	Owl limpet	Black turban
261: Str. F3	9,800	0.2	70.2	2.9	0.7	0.3	20
522	9,700	0.5	79.4	9.5	-	2.7	-
261: Str. F2	9,600	0.7	69.3	0.1	-	-	24.7
548	9,500	0.4	85.1	5.8	<0.1	3.8	0.1
261: Str. F1	9,450	2.8	74.1	<0.1	<0.1	0.8	13.7
608	9,150	0.1	81.4	10	-	1.8	1.6
261:Str. E4	9,100	4.8	75.5	6.2	-	0.8	7.4
261:Str. E3	9,000	1	25.6	30.6	-	-	35.6
261:Str. E2	8,900	1.5	34.6	9.9	-	1	47.2
261:Str. E1	8,700	0.8	42.6	0.9	-	0.9	46.4
261: Str. C	6,700	0.2	91.5	1.6	0.1	0.3	0.1
Otter Cave Str. 3	6,600	0.1	25.4	4.2	-	8.4	54.1
557	6,200	-	1.5	2.4	78.8	-	3.7
481: Red abalone lens	6,000	0.3	11.9	0.5	68	1.2	4.4
492N: 212–230 cm	5,300	0.1	36.8	1.2	21.8	5.6	26.1
603: Str. 4	4,320	39.5	15.8	6.5	19.5	0.5	1.3
603: Str. 3	4,060	24.6	18.6	17.6	24.2	-	1.1
503N: Str. 2	3,650	9.1	43	16.4	3.3	2.5	6.7
261: Str. A	3,300	10.1	53.3	6	8.2	0.3	6.6
525: 22–27	3,100–2,500	10.3	12.5	28.9	9.2	1.8	15.1
87: West Unit, Str. 1	3,050	3	69.7	2.2	1	0.1	4.1
504N: Str. 12	2,800	1.1	72	1.4	-	-	-
603: Str. 2	2,440	19.2	44.3	3	12.7	0.3	-
488N: 45–60 cm	2,400	5.8	33.3	2.7	1.6	9.4	5.6
525D: Str. 9	1,700	0.2	62.7	9.5	-	-	1.8
510N: Str. 6	1,650	0.2	67.1	18.7	0.2	1	4.2
503S: 15–25 cm	1,600	3.8	58.7	0.9	1.1	4.6	25.3
232: A4 soil	1,200	5.2	28.9	8.2	5.6	0.2	2.8
481: Str. 1	1,150	6.8	59.5	6.7	9.1	2.8	2.8
525D: Str. 3	950	0.1	26.6	9.4	0.1	21.5	21.7
492N: 48–64 cm	800	0.3	88.5	3.3	-	-	1.1
470: Str. 1	360	2.7	59.1	13.3	3	2.2	9.5
163: 0–100cm	220	0.5	80.1	2.9	1.1	0.4	4.4

[a] Includes only ^{14}C dated components and major dietary contributors (data from Walker and Snethkamp 1984, Vellanoweth et al. 2002, Walker et al. 2002, Rick 2004, Vellanoweth et al. 2003 unpubl. data).
[b] Sea urchin (*Strongylocentrotus* spp.).

productivity of abalone and other shellfish populations in these areas. Given the significance of shellfish to the islanders during the early and middle Holocene, and the highly visible feeding behavior of sea otters, it is possible that otters were intentionally eradicated from Native foraging areas to help increase and maintain the productivity of local shellfish beds. If sea otter furs were as valued by middle Holocene islanders as they were by the historic Chumash, however, otter populations may have been managed in such a way that they were kept out of areas surrounding villages or other important shellfish beds, yet maintained in more remote areas, including offshore islands.

Sea Urchin Lenses: Evidence for Local Kelp Deforestation?

If sea otter populations on the Channel Islands were significantly reduced by Native hunting for much of the past 7,500 years, data from the

Aleutians suggest that we might also expect to find evidence for localized eruptions of urchin populations, kelp deforestation, and urchin barrens in San Miguel Island shell middens. It seems unlikely that such ecological changes would occur, however, as long as California sheephead and large spiny lobsters, both also important urchin predators, were common in Channel Island waters. Prehistoric patterns of lobster exploitation are poorly known because their remains do not appear to preserve in archaeological sites, but Native peoples fished for sheephead throughout the Holocene (Rick et al. 2001). There is only limited evidence for intensive fishing on the Channel Islands until the past 3,000 to 4,000 years, when human population levels and sedentism also may have increased significantly. On San Clemente Island, Salls (1991) argued that intensive Native American fishing for sheephead may have led to the creation of urchin barrens and heavy urchin predation by Native peoples, a process visible as a dense concentration of sea urchin tests in a shell midden stratum at the Eel Point site dated to about 3,500 years ago. Significantly, such evidence does not occur until about 5,000 years after Eel Point was first occupied.

Although few have been dated, similar urchin lenses (dense concentrations of sea urchin tests) have been noted in a number of shell middens from San Miguel and the other northern Channel Islands (Sharp 2000, Erlandson et al. 2004). Could such urchin lenses represent archaeological evidence for localized phase shifts in Channel Island kelp forests caused by humans? At this time, we have only very preliminary data with which to address this question. Sea urchin remains are present in almost every San Miguel Island shell midden that has been tested, but they are usually found in very small quantities. So far, discrete sea urchin lenses in San Miguel sites appear to date primarily to the past 4,500 years, when human populations had grown substantially and the regional importance of fishing was beginning to increase (Table 4). One exception to this generalization is found in a nearly 9,000 year old stratum at Daisy Cave, where evidence for sea otter hunting and sheephead fishing are found with a shellfish assemblage where sea urchin remains made up almost 5% of all marine shell. Even for the late Holocene, urchin lenses appear to make up a small proportion of the shellfish in most Channel Island sites. In a column sample excavated from a 3 m deep shell midden at SMI-525 near Point Bennett, a deposit that spans much of the past 3,200 years, sea urchin generally makes up less than 3–5% of the recovered shell in 30 discrete strata, but comprises between 10–28% of the shell in samples from five strata (see Walker and Snethkamp 1984).

It is not clear if such fluctuations represent short-term ecological phase shifts caused by human predation or natural variations in the abundance of urchins and other resources caused by El Niño/La Niña cycles or other changes in water temperature or storm cycles, disease epidemics, or other ecological processes (see Ebeling et al. 1985, Ambrose et al. 1993). On San Miguel Island, an apparent increase in the number of urchin-rich midden components through time suggests that humans may have played some role. If such urchin lenses reflect a growing human impact on San Miguel kelp forests, however, dense concentrations of abalones, mussels, and other shellfish in overlying strata at the same sites suggest that such impacts were probably short-lived and localized in scale.

SUMMARY AND CONCLUSIONS

Archaeological data from San Miguel Island indicate that the Chumash and their predecessors collected mussels, abalones, urchins, and other shellfish from Channel Island shorelines for at least 11,500 years, fished in kelp forest and other near shore habitats for 10,000 years or more, and hunted sea otters and other marine mammals for at least 9,000 years. The coexistence of humans with productive sea otter, shellfish, and near shore fish populations on San Miguel through the Holocene—even as human populations, technological sophistication, and trade increased dramatically—raises fundamental questions about the management of similar fisheries along the California Coast today. We have argued that human control of otter populations may have been crucial to the development of a productive red abalone fishery between about 7,300 and 3,000 years ago. Although more speculative, we also suggested that the combination of intensive otter hunting and sheephead fishing may have created localized urchin barrens as sea urchin populations were temporarily released from predatory controls. If so, current evidence suggests that such small-scale perturbations in San Miguel Island kelp forest communities were limited primarily to the last 3,000 to 4,000 years, when Native populations were larger and more sedentary, and the intensity of near shore fishing was increasing.

This hypothetical model of Native control of sea otter populations might be interpreted as further evidence for resource depression or a "tragedy of the commons" in prehistoric California. It can just as easily be viewed, however, as a case of successful management of nearshore marine fisheries by Native peoples. After all, unlike the European and American hunting that followed them, the Island Chumash appear to have hunted sea otters for millennia, without island-wide extirpation or extinction. On San Miguel, they seem to have done so while maintaining long-term and sustainable harvests of shellfish and fish, despite considerable population growth and technological innovation (Erlandson et al. 2004). Additional study is clearly needed, but it is possible the Island Chumash intentionally enhanced the productivity of local shellfish and fish harvests by controlling otter populations. Such ecological management might logically grow from observations of animal behavior and the changes engendered in local fish and shellfish populations as sea otters were depleted or extirpated from local village territories.

Although preliminary, our research provides some potential insights into the modern management of sea otter, shellfish, and fish populations along the California Coast. If we wish to expand the range of sea otters and protect local fisheries, for instance, we might consider adopting a hypothetical Chumash-style management model that excludes otters from certain areas where productive abalone or urchin fisheries have existed in the recent past, while encouraging the development of new otter populations in marine sanctuaries or marine protected areas where commercial harvest of such shellfish is prohibited.

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